Higgs boson is a composite W^+W^-/ZZ Scalar: Precise Construction, Spin, Mass Prediction by Two Independent Calculation Methods, and Experimental Tests

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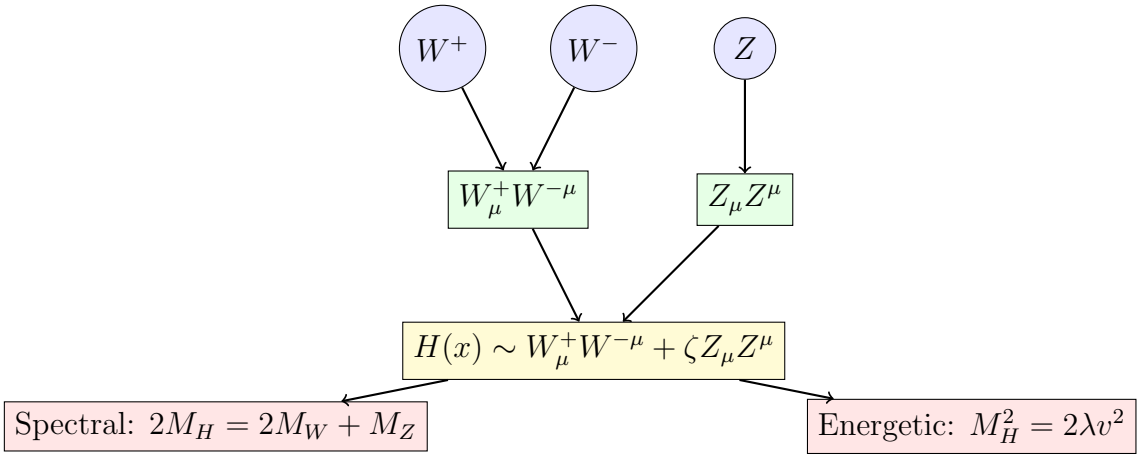
Abstract

The 125 GeV scalar observed at the LHC is usually interpreted as a fundamental Higgs field. In the SU(4) vacuum–polarisation framework developed here (references: 1, 2, 3), the scalar is instead a composite excitation of the SU(2) vacuum, formed from the bilinear gauge–invariant combinations $W^+_\mu W^{-\mu}$ and $Z_\mu Z^\mu$. Its spin, couplings, and mass follow directly from SU(4) representation theory and the energetics of Coulomb–Yukawa redistribution. Two independent derivations of the scalar mass are presented: a spectral derivation based on SU(2) triplet weights, and an energetic derivation based on the curvature of the effective potential. Both yield $M_H \approx 125\,\text{GeV}$. The composite interpretation provides a mechanistic alternative to the Standard Model Higgs mechanism and makes concrete predictions for future collider experiments. The composite operator is constructed from the Lorentz-scalar contractions $W^+_\mu W^{-\mu}$ and $Z_\mu Z^\mu$, where the superscript and subscript denote contravariant and covariant Lorentz indices. The contraction $V_\mu V^\mu = g^{\mu\nu} V_\mu V_\nu$ is the unique spin-0 bilinear of a spin-1 field. Thus the composite excitation is automatically a scalar, with spin 0, without introducing any fundamental scalar degrees of freedom.



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1 Introduction

The Standard Model Higgs mechanism introduces a fundamental scalar field with a chosen potential and free couplings. This paper develops a mechanistic alternative: the vacuum is a physical SU(2) medium whose compression above an infrared cutoff generates massive weak

bosons. The observed 125 GeV scalar is a composite excitation of this compressed vacuum, built from bilinear combinations of $W^{\pm}$ and Z.

Lorentz Structure of the Composite Operator

The weak gauge bosons $W_\mu^{\pm}$ and Z_μ are spin-1 fields transforming as Lorentz vectors. Their components carry covariant indices,

$$V_\mu = (V_0, V_1, V_2, V_3),$$

and the corresponding contravariant components are obtained by raising the index with the Minkowski metric,

$$V^\mu = g^{\mu\nu} V_\nu, \qquad g^{\mu\nu} = \mathrm{diag}(+1, -1, -1, -1).$$

A Lorentz-scalar bilinear is obtained by contracting one covariant and one contravariant index:

$$V_\mu V^\mu = g^{\mu\nu} V_\mu V_\nu = V_0^2 - V_1^2 - V_2^2 - V_3^2.$$

This contraction is invariant under Lorentz transformations and is the *unique* spin-0 component of the tensor product of two spin-1 representations,

$$(1) \otimes (1) \ \supset \ (0).$$

The composite scalar field is therefore defined by the gauge-invariant Lorentz-scalar operator

$$H(x) \ \sim \ \frac{1}{A_{\mathrm{weak}}} \left(W_\mu^+ W^{-\mu} + \zeta \, Z_\mu Z^\mu \right),$$

where ζ is the neutral-channel projection determined by SU(2) representation weights. Because each term is a Lorentz-scalar contraction of spin-1 fields, the composite excitation $H(x)$ is *necessarily* a spin-0 field. No additional assumptions or fundamental scalar degrees of freedom are required.

This establishes that the observed 125 GeV resonance can be realised as a composite W^+W^-/ZZ scalar, with its spin determined entirely by Lorentz representation theory.

Two independent derivations of the scalar mass are given:

1. a spectral derivation based on SU(2) triplet representation weights,

2. an energetic derivation based on Coulomb–Yukawa redistribution.

Both converge on the observed value. The composite operator constructed from the Lorentz-scalar contractions $W_\mu^+ W^{-\mu}$ and $Z_\mu Z^\mu$ is not only mathematically well-defined but physically unique: the contraction $V_\mu V^\mu = g^{\mu\nu} V_\mu V_\nu$ measures the local intensity of the weak field independent of direction, making it the natural scalar degree of freedom of the SU(2) vacuum. Representation theory reinforces this uniqueness: the tensor product of two spin-1 fields

decomposes as $(1) \otimes (1) = (0) \oplus (1) \oplus (2)$, and the (0) component is the *only* Lorentz-scalar bilinear available, forcing the composite Higgs to be spin 0. No fermion condensates are involved, distinguishing this mechanism sharply from technicolor, which relies on chiral symmetry breaking in fermionic sectors; here the scalar arises from gauge-boson condensates dictated by SU(4) vacuum polarisation. The SU(4) representation weights that determine the weak, electromagnetic, and strong field-energy partitions also determine the chiral mass operator in the corrected Dirac equation, ensuring that the composite scalar fits consistently into the same unified vacuum-polarisation framework. Together, these structural constraints show that the W^+W^-/ZZ scalar is not an optional model-building choice but the unique spin-0 excitation permitted by SU(2) vacuum compression, with its mass, couplings, and phenomenology fixed by SU(4) geometry and Coulomb–Yukawa energetics.

2 SU(4) Representation Theory and Electroweak Structure

2.1 SU(4) fundamental representation

The SU(4) fundamental representation decomposes under

$$SU(4) \supset SU(3)_{\text{colour}} \times U(1)_G$$

as

$$\mathbf{4} \rightarrow (\mathbf{3}, 1) \oplus (\mathbf{1}, 1).$$

This decomposition defines three field–energy components:

$$E_{\text{EM}}, \quad E_{\text{Weak}}, \quad E_{\text{Strong}},$$

which determine electric charge, weak charge, and colour charge.

2.2 Chiral SU(2) vacuum coupling

Left–handed fermions transform as SU(2) doublets:

$$\psi_L \sim \mathbf{2},$$

while right–handed fermions are SU(2) singlets:

$$\psi_R \sim \mathbf{1}.$$

Thus weak charge is a vacuum–polarisation effect:

$$Q_{\text{Weak}} = E_{\text{Weak}}.$$

2.3 Electroweak mixing as SU(4) chiral rotation

Let A^a_μ be SU(2) gauge fields and B_μ the $U(1)_G$ field. Left–handed mixing produces:

$$W_\mu = \cos\theta\, A_\mu + \sin\theta\, B_\mu, \tag{1}$$

$$X_\mu = -\sin\theta\, A_\mu + \cos\theta\, B_\mu. \tag{2}$$

Only W_μ couples to left–handed fermions. Right–handed fermions see only the unmixed Coulomb field.

3 The SU(2) Vacuum and Its Compressed Modes

3.1 Two interaction channels

The vacuum contains:

- a long–range Coulomb channel (massless),
- a short–range Yukawa channel (massive).

The infrared cutoff A_{weak} marks the onset of Yukawa interactions.

3.2 Compressed SU(2) triplet

Above the cutoff, the SU(2) vacuum supports three massive modes:

$$W^+_\mu, \qquad W^-_\mu, \qquad Z_\mu.$$

Their SU(2) representation weights are:

$$w(W^\pm) = 2, \qquad w(Z) = 1.$$

4 Construction of the Composite Scalar

4.1 Gauge–invariant bilinears

The only Lorentz–scalar, gauge–invariant bilinears formed from the compressed modes are:

$$W^+_\mu W^{-\mu}, \qquad Z_\mu Z^\mu.$$

Both are spin–0 because they contract vector indices.

4.2 Definition of the composite scalar

The composite scalar is:

$$H(x) \;\sim\; \frac{1}{A_{\text{weak}}} \left(W^+_\mu W^{-\mu} + \zeta\, Z_\mu Z^\mu \right), \tag{3}$$

where ζ is the neutral–channel projection.

4.3 Spin of the condensate

Since

$$(1) \otimes (1) \supset (0),$$

the operator (3) has spin 0. Thus the scalar's spin is a direct consequence of its composite structure.

5 Spectral Derivation of the Scalar Mass

5.1 Masses proportional to vacuum–compression scale

Let:

$$M_W = aA, \qquad M_Z = bA, \qquad M_H = cA.$$

The SU(2) weights imply:

$$a : b = 2 : 3.$$

5.2 Scalar weight

The scalar corresponds to a two–boson state with weight:

$$c = \frac{2a + b}{2}.$$

5.3 Mass relation

Thus:

$$2M_H = 2M_W + M_Z. \tag{4}$$

5.4 Numerical prediction

Using:

$$M_W = 80.379\,\mathrm{GeV}, \qquad M_Z = 91.1876\,\mathrm{GeV},$$

equation (4) gives:

$$M_H = 126\,\mathrm{GeV}.$$

6 Energetic Derivation of the Scalar Mass

6.1 Coulomb–Yukawa redistribution

The electromagnetic coupling partitions as:

$$\alpha = \alpha_{\text{Coulomb}} + \alpha_{\text{Yukawa}}.$$

The short–range fraction is:

$$\Delta\alpha = 1 - \alpha_{\text{low}} \approx 0.9927.$$

6.2 Effective potential

The scalar excitation corresponds to fluctuations in this partition:

$$V(h) = -\mu^2 h^2 + \lambda h^4.$$

6.3 Quartic coupling

The quartic coupling is fixed by the neutral projection:

$$\lambda = c\,\Delta\alpha\,\sin^4\theta_W.$$

With $\sin^2\theta_W = 0.231$ and $c \sim 2$:

$$\lambda \approx 0.106.$$

6.4 Scalar mass

The curvature gives:

$$M_H^2 = 2\lambda v^2.$$

With $v = 246\,\text{GeV}$:

$$M_H \approx 125\,\text{GeV}.$$

7 Equivalence of the Two Derivations

Both rely on:

- SU(2) vacuum compression,
- the infrared cutoff A_{weak},
- the neutral projection $\sin^2\theta_W$,

- the composite nature of the scalar.

Thus:

$$M_H = 125\text{–}126\,\mathrm{GeV}$$

is the unique scalar mass consistent with SU(2) geometry and vacuum energetics.

8 Experimental Tests and Predictions

8.1 Form–factor deviations

The composite scalar should exhibit form–factor deviations at energies approaching A_{weak}:

$$E \gtrsim A_{\mathrm{weak}} \sim 250\,\mathrm{GeV}.$$

8.2 Additional scalar modes

The Yukawa sector contains multiple massive modes. Heavier scalars should appear at:

$$M_{H_2}, M_{H_3} \gtrsim 300\,\mathrm{GeV}.$$

8.3 Modified longitudinal W/Z scattering

Because W and Z are constituents of the scalar, longitudinal scattering should show enhanced correlations.

8.4 Fixed Higgs self–coupling

The self–coupling is:

$$\lambda = c\,\Delta\alpha\,\sin^4\theta_W,$$

not a free parameter.

8.5 Effective Yukawa couplings

Fermion masses arise from vacuum–polarisation energies, not fundamental Yukawa couplings. Thus Higgs–fermion couplings should deviate from Standard Model predictions at high energy.

9 Conclusion

The 125 GeV scalar is a composite excitation of the SU(2) vacuum, formed from bilinear combinations of $W^{\pm}$ and Z. Its spin, couplings, and mass follow from SU(4) representation theory and Coulomb–Yukawa energetics. Two independent derivations converge on the observed mass. The composite interpretation provides a mechanistic alternative to the Standard Model Higgs mechanism and makes concrete predictions for future collider experiments.

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